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National Renewable Energy Laboratory

Review of Fast Pyrolysis of Biomass

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Outline

- Pyrolysis of biomass
- Fast pyrolysis reactors
- Product collection
- Liquid properties
- Liquid applications
- Barriers to development

Biomass Pyrolysis Products

	Liquid	Char	Gas
FAST PYROLYSIS moderate temperature short residence time	75%	12%	13%
CARBONISATION low temperature long residence time	30%	35%	35%
GASIFICATION high temperature long residence time	5%	10%	85%

Fast Pyrolysis of Biomass

Fast pyrolysis is a thermal process that rapidly heats biomass to a carefully controlled temperature (~500°C), then very quickly cools the volatile products (<2 sec) formed in the reactor

- Offers the unique advantage of giving a liquid that can be stored and transported.
- Has been developed in many configurations
- At present is at relatively early stage of development

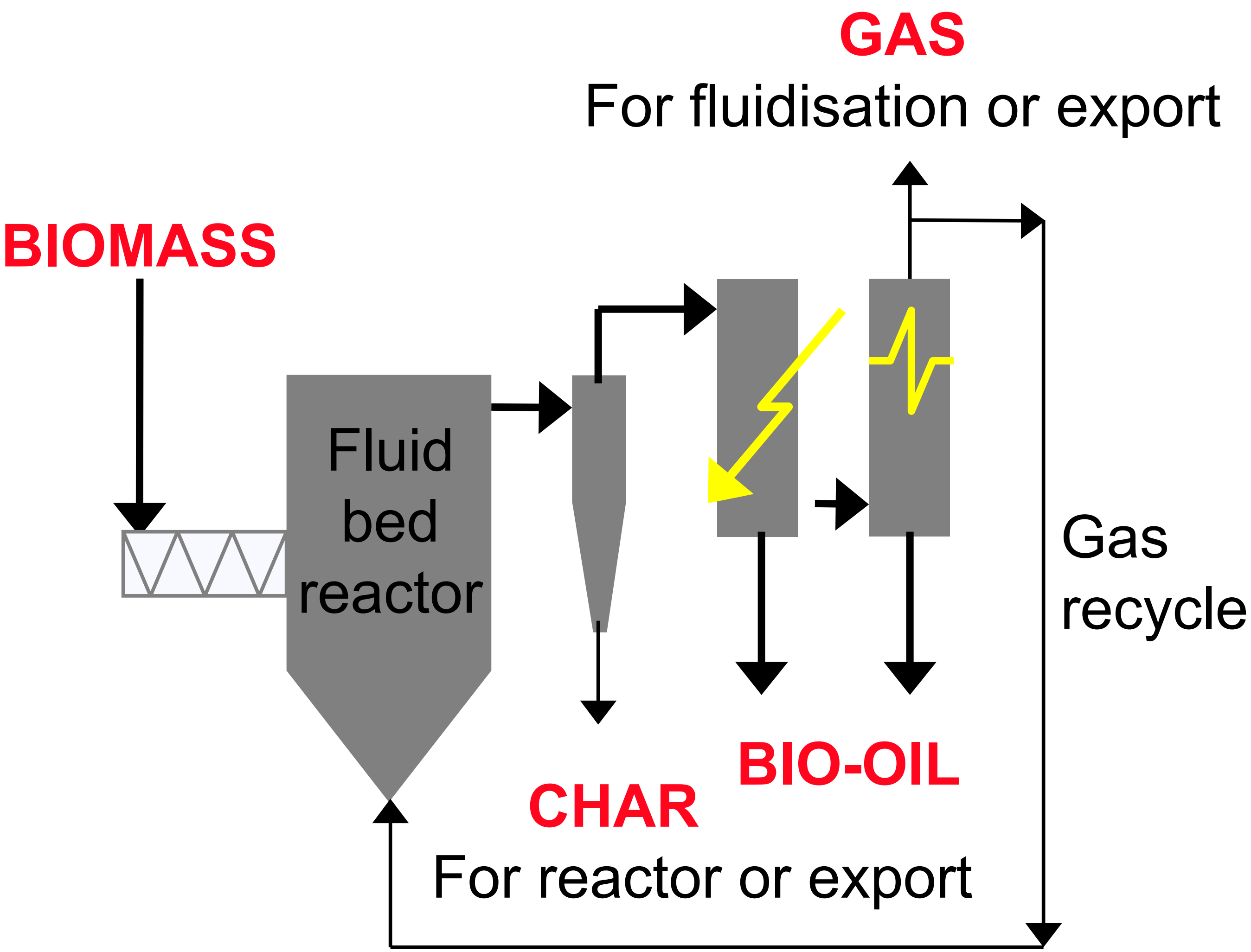
Process Requirements

Drying	<10% moisture. Feed and reaction water end up in bio-oil
Comminution	-2mm (bubbling bed), -6 mm (CFB)
Fast pyrolysis	High heat rate, controlled T, short residence time
Char separation	Efficient char separation needed
Liquid recovery	By condensation and coalescence.

Operational Pyrolysis Units

Fluid beds	400 kg/h at Dynamotive
	250 kg/h at Wellman (UK)
	20 kg/h at RTI
	Many research units
CFBs	1000 kg/h at Red Arrow (Ensyn)
	20 kg/h at VTT (Ensyn)
Rotating cone	120 kg/h at BTG (Netherlands)
Vacuum	3500 kg/h at Pyrovac
Others	350 kg/h (Fortum, Finland)

Bubbling Fluid Bed Pyrolysis



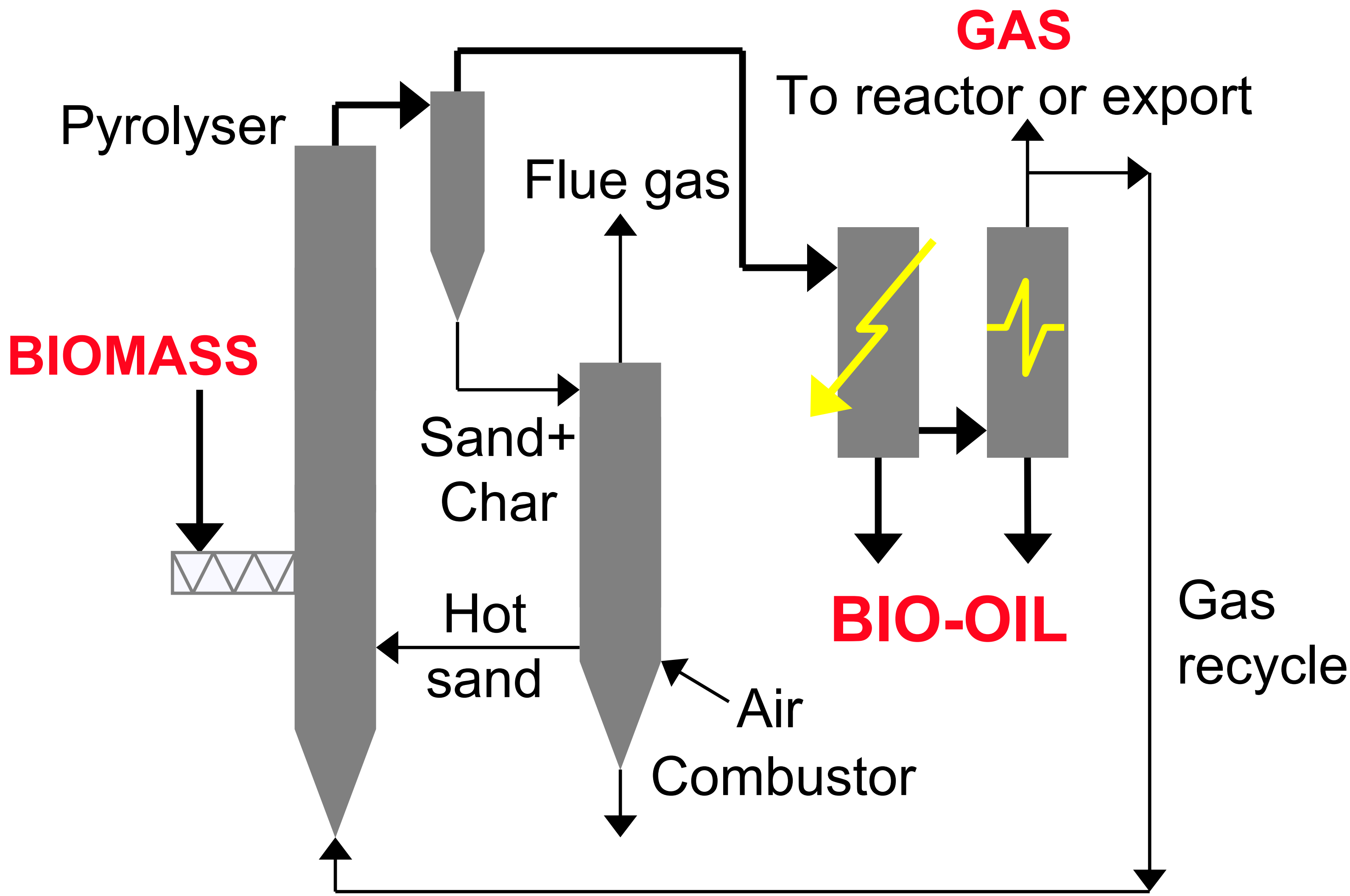
Bubbling Fluid Bed

250 kg/h pilot plant at Wellman, UK

Fluid Bed Reactors

- Good temperature control,
- Char removal is usually by ejection and entrainment; separation by cyclone,
- Easy scaling,
- Well understood technology since first experiments at University of Waterloo in 1980s
- Small particle sizes needed,
- Heat transfer to bed at large scale has to be proven.

Circulating Fluid Beds



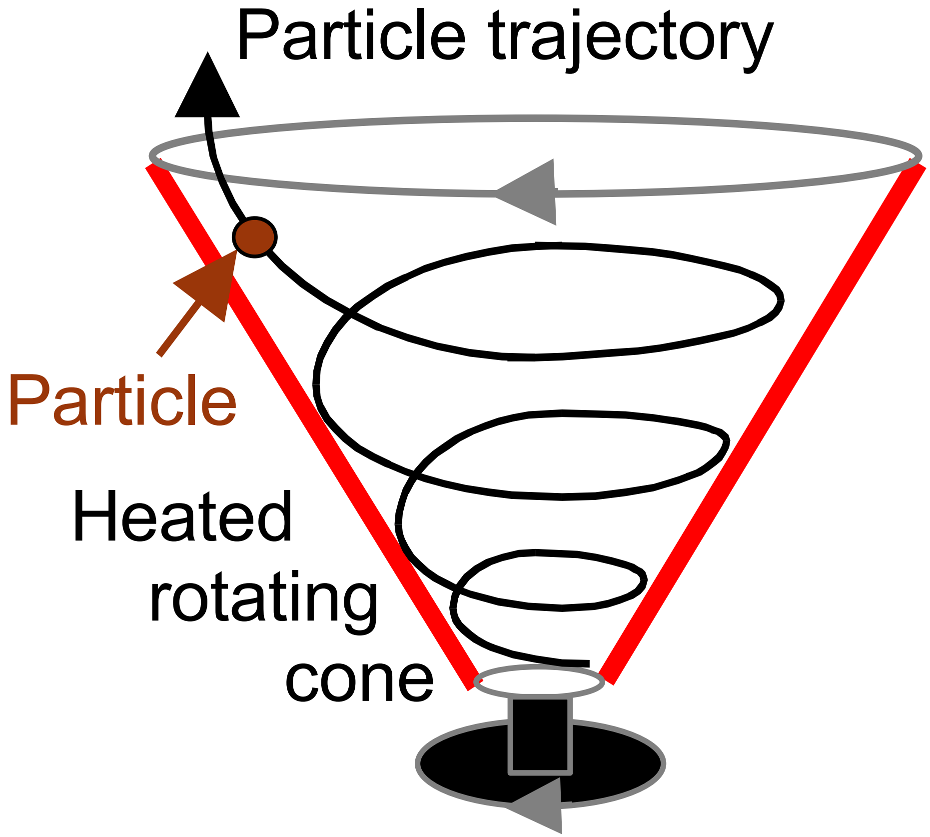
CFB and Transported Beds

- Good temperature control in reactor,
- Larger particle sizes possible,
- CFBs suitable for very large throughputs,
- Well understood technology,
- Hydrodynamics more complex,
- Char is more attrited due to higher velocities; separation is by cyclone,
- Closely integrated char combustion requires careful control,
- Heat transfer to bed at large scale has to be proven.

Rotating Cone (BTG)

- Centrifugation drives hot sand and biomass up rotating heated cone;
- Vapors are condensed;
- Char is burned

  and hot sand is recirculated.



Vacuum Moving Bed

- Developed at Université Laval, Canada, scaled up by Pyrovac
- Pilot plant operating at 50 kg/h
- Demonstration unit operating at 3.5 t/h
- Pyrolysis liquid yield 35-50%
- Analogous to fast pyrolysis as vapor residence time is similar.

Char Removal

- Char acts as a vapor cracking catalyst so rapid and effective removal is essential.
- Cyclones are usual method of char removal. Fines pass through and collect in liquid product.
- Hot vapor filtration gives high quality char free product. Char accumulation cracks vapors and reduces liquid yield (~20%). Limited experience is available.
- Liquid filtration is very difficult due to nature of char and pyrolytic lignin.

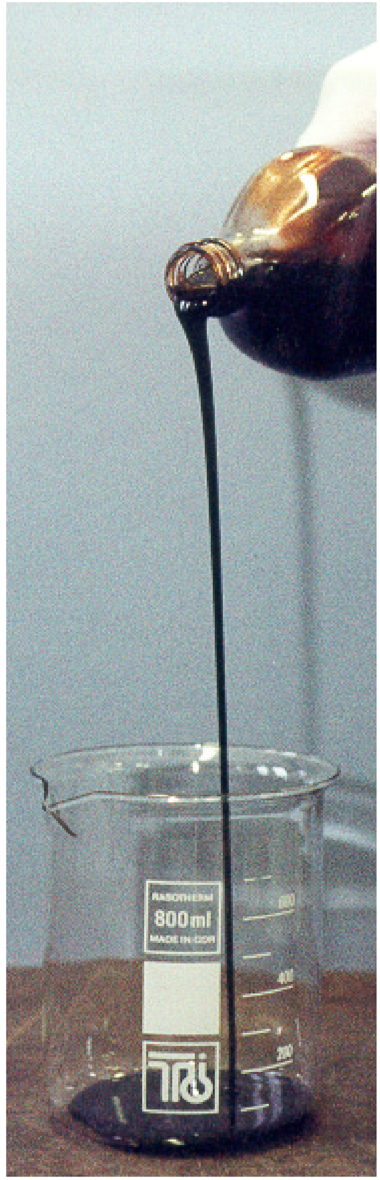
Liquid Collection

- Primary pyrolysis products are vapors and aerosols from decomposition of holocellulose and lignin.
- Liquid collection requires cooling and agglomeration or coalescence of aerosols.
- Simple heat exchange can cause preferential deposition of heavier fractions leading to blockage.
- Quenching in product liquid or immiscible hydrocarbon followed by electrostatic precipitation is preferred method.

Fast Pyrolysis Liquid

Bio-oil is water miscible and is comprised of many oxygenated organic chemicals.

- Dark brown mobile liquid,
- Combustible,
- Not miscible with hydrocarbons,
- Heating value ~ 17 MJ/kg,
- Density ~ 1.2 kg/l,
- Acid, pH ~ 2.5,
- Pungent odour,
- “Ages” - viscosity increases with time



Properties

- The complexity and nature of the liquid results in some unusual properties
- Due to physical-chemical processes such as:
  - Polymerization/condensation
  - Esterification and etherification
  - Agglomeration of oligomeric molecules
- Properties of bio-oil change with time:
  - Viscosity increases
  - Volatility decreases
  - Phase separation, deposits, gums

Upgrading of Pyrolysis Liquid

Physical Methods

- Filtration for char removal,
- Emulsification with hydrocarbons,
- Solvent addition,

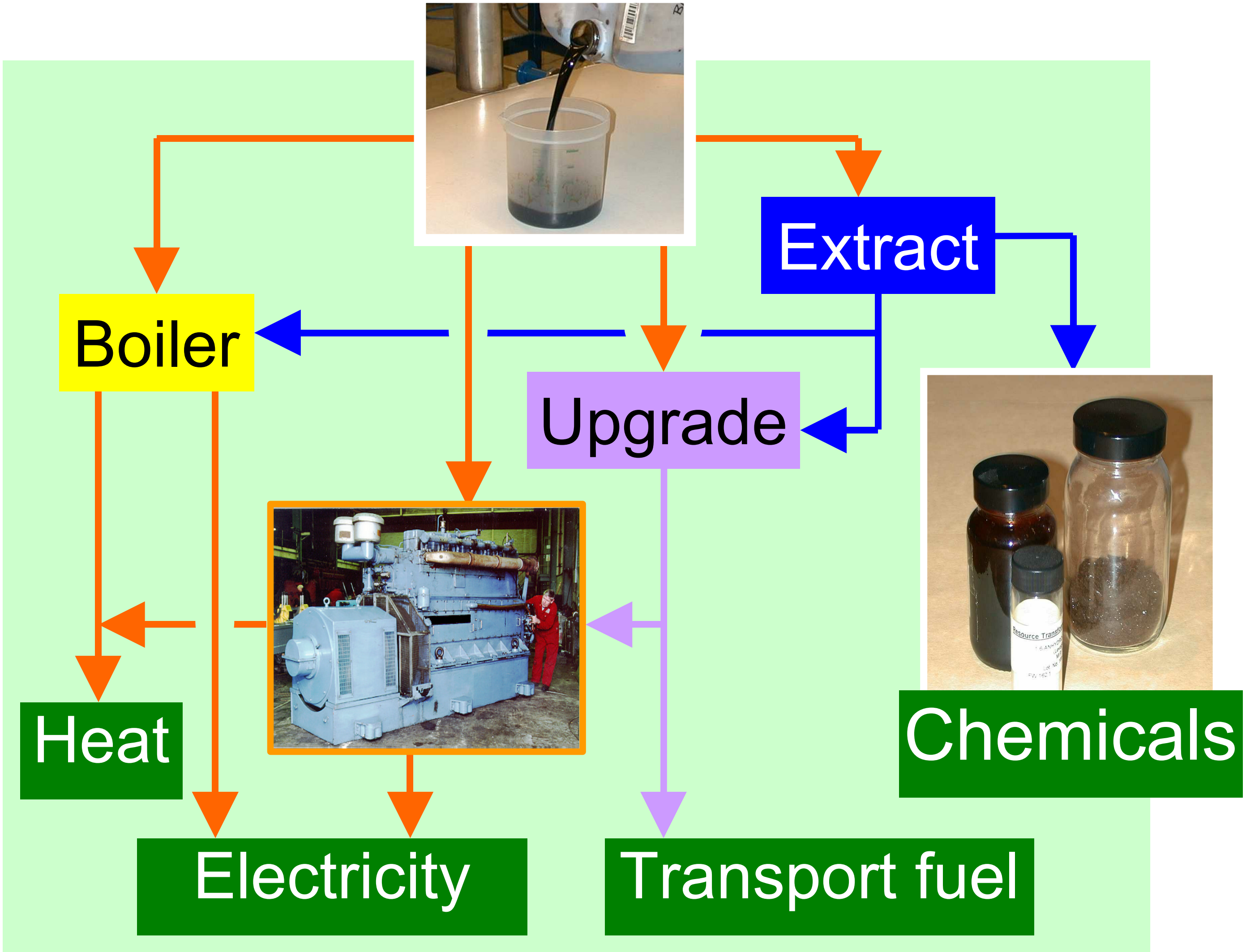
Chemical Methods

- Reaction with alcohols,
- Catalytic deoxygenation:

  Hydrotreating,

  Catalytic (zeolite) vapor cracking.

Applications



Demonstrated Applications

Electricity	diesel, turbine, Stirling;
Heat	CHP and boiler;
Transport fuels	upgrading, emulsions;
Bulk chemicals	e.g. resins, fertilizers;
Fine chemicals	e.g. levoglucosan

Why Is Bio-oil Not Used More?

- Cost : 10% – 100% more than fossil fuel,
- Availability: limited supplies for testing
- Standards; lack of standards and inconsistent quality inhibits wider usage,
- Incompatibility with conventional fuels,
- Unfamiliarity of users
- Dedicated fuel handling needed,
- Poor image.

What Is Needed?

- Process development to improve product quality, reduce costs,
- Research into improving product quality including setting norms and standards for producers and users,
- Environment health and safety issues in handling, transport and usage,
- Encouragement for developers to implement processes; and users to implement applications.

Conclusions

Many challenges including:

- Scale-up,
- Cost reduction,
- Better oil quality,
- Norms and standards for bio-oil,
- Information dissemination.

The unique advantage of bio-oil:

liquid that can be stored and transported

Can be used for

fuel and/or chemicals production

Information on Pyrolysis of Biomass

Pyrolysis Network PyNe

15 European Countries and USA

http://www.pyne.co.uk

Newsletter (two/year) available on-line